International Journal of Engineering and Modern Technology (IJEMT) E-ISSN 2504-8848
P-ISSN 2695-2149 Vol 9. No. 3 2023 www.iiardjournals.org

Experimental Assessment of The Effect of Sugar as an Admixture on the Setting Time of Cement and Compressive Strength of Concrete

Mokanmiyo Adedeji Olawale[1*]
[1]Department of Civil & Environmental Engineering,
Kwara State University Malete, Nigeria
[1]olawalemokanmiyo@gmail.com

DOI: 10.56201/ijemt.v9.no3.2023.pg203.213

Abstract

This study was carried out with the fundamental aim of conducting experimental investigations into the influence of sugar as an admixture on both the setting time of cement and the compressive strength of concrete. The research involved the variation of the proportion of cement replaced by sugar at specific weight percentages, including 0.0%, 0.06%, 0.08%, 1%, 2%, and 3%. The aim of this experiment was to determine the effect of sugar as an admixture on the setting time of cement paste and the determination of the compressive strength of the obtained concrete. On a global scale, this research addresses the pressing issue of the substantial demand for cement and its profound environmental implications. The study explores innovative approaches to partially substitute cement in concrete mix, thereby fostering sustainability within the construction sector. The experiment of this study have yielded noteworthy outcomes. Particularly, at the admixture levels of 0.06% and 0.08% sugar by weight of cement, the compressive strength results not only met but exceeded the expectations, surpassing even the performance of the control concrete M15 sample, while retarding the setting time of cement paste. These findings present a compelling argument for the potential utilization of sugar as an admixture in cementitious materials, offering promising prospects for sustainable and environmentally responsible construction practices. This research adds to the broader discourse on sustainable construction and emphasizes the potential benefits of sugar admixture in enhancing concrete properties while cushioning the environmental effect attached with conventional cement usage.

Keywords: *Admixture, Compressive Strength, Concrete, Portland Limestone Cement (PLC), Setting Time, Sugar.*

I. Introduction

In construction, projects are executed by adhering to guidelines and procedures; For example, temperature and humidity are fundamental factors to be considered. Practically, to achieve the desired set of results, the procedures are to be strictly adhered to. Hydration of cement is also subject to weather and temperature, under high weather conditions above 38^{o}C early hydration occurs in cement [1], consequential to this, high strength is gained in concrete at the early stages but reduces considerably at the latter stages. Plastic shrinkage is caused due to the quick evaporation of water [2], and as a result, the cooling causes cracking and tensile stresses within the concrete [3]. More so, this issue affects greatly and negatively practically globally, as concrete might lose its plasticity under severe weather conditions while being transported to the site where it is needed, this can be economically draining.

However, an impediment in the setting time of cement paste can be reached by introducing a retarder to the concrete mix [4]. The function of a retarder is to delay the hardening of cement paste by halting the rapid set made manifest by tricalcium aluminates but fails to change the structure of hydration products [3]. These retarders are instrumental to catering for impediments on job site, for example, traffic issues while transporting concrete, especially in developing countries like Nigeria and or severe weather conditions that prompt concrete to set quicker than expected.

Furthermore, many researchers have experimented with a vast number of retarders some of them include calcium sulphate or gypsum [5]–[8] starch [9], [10], salts of acids [5]. Albeit, considering all the aforementioned options seems to be relatively more expensive and less economical to using a possibly viable option which is sugar.

This study experimentally looks into using sugar as an admixture in concrete by partially displacing cement by percentage weight of 0.0%, 0.06%, 0.08%, 1%, 2%, and 3%, principally focusing on its effect on the setting time of cement paste and compressive strength of concrete. Sugar, being economical, sustainable [11] and easily accessible poses as a great option.

On a global scale, this study aims to achieve a more sustainable environment by partially reducing the amount of cement being used which can have numerous positive effects on sustainability [12], including lowered energy consumption, resource maintenance, reduced carbon emissions, and cost saving through the replacement of cement by percentage weight with sugar, while maintaining the strength of concrete and performance requirements to ensure the safety and longevity of construction works and also increasing its setting time so as to impede the wastage of construction materials under extreme weather conditions, especially in the developing worlds.

II. Methodology

Materials

Cement: Portland Limestone Cement PLC (BUA cement) was used, with Specific Gravity of 3.15.

Fine Aggregates: locally available sharp sand was used, which passes through the 4.75mm sieve with a Specific Gravity of 2.6 which satisfies the [13] Limits (2.40- 3.00) for Specific Gravity of fine aggregates.

Coarse Aggregates: Crushed granite was obtained and utilized, the maximum size of the coarse aggregates used was 20mm; with a specific gravity of about 2.64 in conformity with the standards in [14] and [15]

Water: water was obtained from the tap in the laboratory; a water- cement (W/C) ratio of 0.57 was used.

Admixture: Sugar was effected as an admixture in the concrete mix. Sugar was introduced in the concrete mix with five different dosages at 0.06%, 0.08%, 1%, 2%, and 3% by weight of cement, and a control sample was set aside (mix at 0% sugar).

Experimental Setup

Utilizing the Vicat apparatus, the initial setting times and the final setting times of the cement paste were determined for the control sample at 0% sugar and samples with percentage replacements at 0.06%, 0.08%, 1%, 2%, and 3% sugar by weight of cement. Concrete mix design for M15 grade, as per IS 10262-2009, was implemented with the details shown in Table 1. The batched concrete mix for the different samples was cast into steel moulds of dimensions 100mm by 100mm, which were allowed to set for 24 hours before being de-moulded, as shown in Figure 1. The de-moulded concrete cubes were then cured for 7 and 28 days, as depicted in Figure 2. The cured concrete cubes were crushed at 7 and 28 days, as shown in Figure 3.

Table 1: Showing the design mix results.

Name	Value
C:FA:CA	1:2:3.3
W/C	0.57

Figure 1: Cast concrete cubes allowed to set for 24 hours.

Figure 2: Concrete cubes cured for 7 and 28 days.

Figure 3: Crushed concrete cubes.

III. Results and Discussion

A. Results for setting time of cement paste

The following readings were obtained for the setting times of cement paste at 0%, 0.06%, 0.08%, 1%, 2% and 3% as shown in Table 2, Table 3, Table 4, Table 5, Table 6 and Table 7;

Table 2: Showing the initial and final setting time test result at 0%.

S/N	Time (hr : min)	Observation	Penetration (mm)	Remark
1	11:00	Total penetration	40	I.S.T not reached
2	11:05	Total penetration	40	I.S.T not reached
3	12:01	Total penetration	40	I.S.T not reached
4	12:10	Partial penetration	35	I.S.T reached
5	12:58	Partial penetration	8	I.S.T reached
6	16:28	No penetration	0	F.S.T reached

From the result from Table 2, it is evident that the initial setting time took 70 minutes, while the final setting time took 328 minutes.

Table 3: Showing the initial and final setting time test result at 0.06%.

S/N	Time (hr : min)	Observation	Penetration (mm)	Remark
1	11:48	Total penetration	40	I.S.T not reached
2	12:30	Total penetration	40	I.S.T not reached
3	12:47	Total penetration	40	I.S.T not reached
4	12:56	Total penetration	40	I.S.T not reached
5	13:03	Total penetration	40	I.S.T not reached
6	13:12	Total penetration	40	I.S.T not reached
7	13:15	Partial penetration	35	I.S.T reached
8	13:20	Partial penetration	30	I.S.T reached
9	19:35	No penetration	0	F.S.T reached

From the result from Table 3, it is evident that the initial setting time took 87 minutes, while the final setting time took 467 minutes.

Table 4: Showing the initial and final setting time test result at 0.08%.

S/N	Time (hr : min)	Observation	Penetration (mm)	Remark
1	12:00	Total penetration	40	I.S.T not reached
2	12:30	Total penetration	40	I.S.T not reached
3	13:30	Partial penetration	34	I.S.T reached
4	13:55	Partial penetration	30	I.S.T reached
5	15:00	Partial penetration	25	I.S.T reached
6	16:00	Partial penetration	20	I.S.T reached
7	19:00	Partial penetration	10	I.S.T reached
8	20:00	No penetration	0	F.S.T reached

From the result from Table 4, it is evident that the initial setting time took 90 minutes, while the final setting time took 480 minutes.

Table 5: Showing the initial and final setting time test result at 1%.

S/N	Time (hr : min)	Observation	Penetration (mm)	Remark
1	11:00	Total penetration	40	I.S.T not reached
2	12:10	Total penetration	40	I.S.T not reached
3	12:40	Total penetration	40	I.S.T not reached
4	13:00	Partial penetration	34	I.S.T reached
5	13:30	Partial penetration	30	I.S.T reached
6	13:50	Partial penetration	27	I.S.T reached
7	15:15	Partial penetration	20	I.S.T reached
8	17:20	Partial penetration	15	I.S.T reached
9	19:15	No penetration	0	F.S.T reached

From the result from Table 5, it is evident that the initial setting time took 120 minutes, while the final setting time took 495 minutes.

Table 6: Showing the initial and final setting time test result at 2%.

S/N	Time (hr : min)	Observation	Penetration (mm)	Remark
1	11:00	Total penetration	40	I.S.T not reached
2	12:20	Total penetration	40	I.S.T not reached
3	12:37	Total penetration	40	I.S.T not reached
4	12:58	Total penetration	40	I.S.T not reached
5	13:13	Partial penetration	36	I.S.T reached
6	13:55	Partial penetration	30	I.S.T reached
7	15:15	Partial penetration	25	I.S.T reached
8	17:20	Partial penetration	15	I.S.T reached
9	19:30	No penetration	0	F.S.T reached

From the result from Table 6, it is evident that the initial setting time took 133 minutes, while the final setting time took 510 minutes.

Table 7: Showing the initial and final setting time test result at 3%.

S/N	Time (hr : min)	Observation	Penetration (mm)	Remark
1	11:00	Total penetration	40	I.S.T not reached
2	12:33	Total penetration	40	I.S.T not reached
3	12:48	Total penetration	40	I.S.T not reached
4	12:53	Total penetration	40	I.S.T not reached
5	13:03	Total penetration	40	I.S.T not reached
6	13:37	Partial penetration	35	I.S.T reached
7	14:15	Partial penetration	35	I.S.T reached
8	16:20	Partial penetration	30	I.S.T reached

9	20:00	No penetration	0	F.S.T reached

From the result from Table 7, it is evident that the initial setting time took 157 minutes, while the final setting time took 540 minutes.

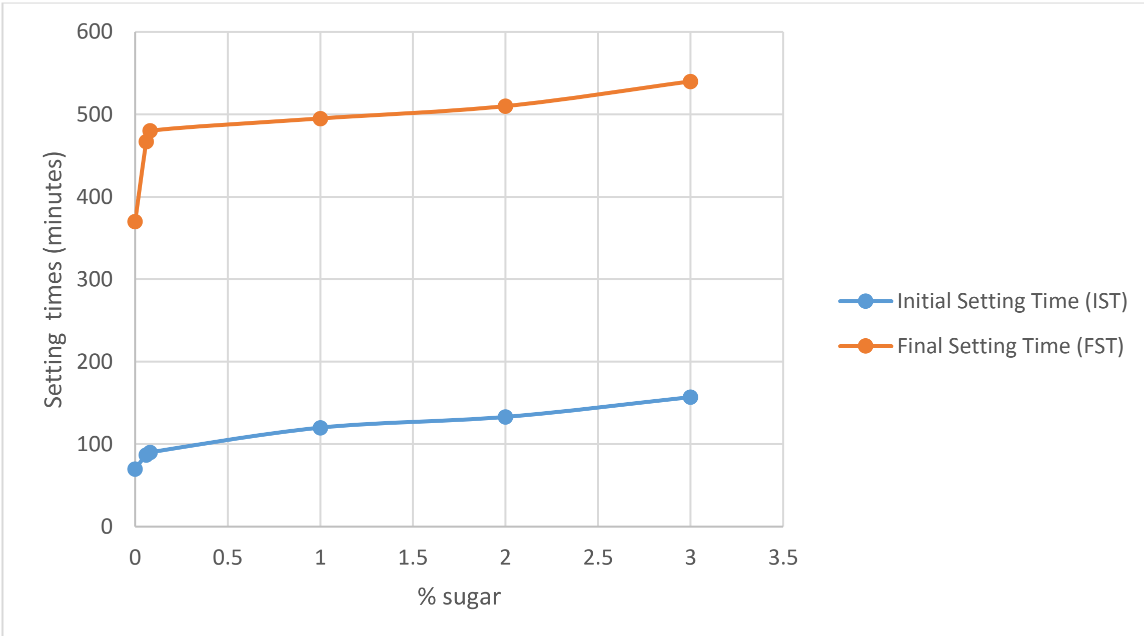

Figure 4: Graph comparing the results for the initial and final setting time of the control cement paste sample and other samples.

B. Results for compressive strength test of concrete

The following readings were obtained for the compressive strength test of concrete at 0%, 0.06%, 0.08%, 1%, 2% and 3% for 7 and 28 days as shown in tables 8 and 9;

Table 8: Showing the compressive strength test result of concrete at 0%, 0.06%, 0.08%, 1%, 2%, 3% at 7 days.

% of sugar in concrete	0%	0.06%	0.08%	1%	2%	3%
Age of cube (days)	7	7	7	7	7	7
Weight of cube (g)	2430	2420	2390	2330	2300	2225
Crushing load (KN)	130	175	170	6	0	0

Table 9: Showing the compressive strength test result of concrete at 0%, 0.06%, 0.08%, 1%, 2%, 3% at 28 days.

% of sugar in concrete	0%	0.06%	0.08%	1%	2%	3%
Age of cube (days)	28	28	28	28	28	28
Weight of cube (g)	2433	2466	2400	2333	2350	2225
Crushing load (KN)	193	260	260	10	0	0

Drawing insights from the outcomes obtained through the concrete cube specimens subjected to crushing at both 7 and 28-day curing intervals, carefully outlined within Tables 8 and 9 correspondingly, an obvious pattern emerges. It becomes vivid that the compressive strength of concrete experiences a relative increase to the control mix sample followed by a subsequent decline, a phenomenon closely associated with the progressive inclusion of sugar as an admixture. This observation shows the presence of a nonlinear pattern inherent in the obtained results, indicative of a complex relationship between sugar content and compressive strength.
Using Equation 1, the resulting data pertaining to compressive strengths for the 7-day and 28-day curing periods are shown in Table 10;

$$Compressive\ strength\ \left(\frac{N}{mm^2}\right) = \frac{Crushing\ load\ P\ (KN)}{Area\ A\ (mm^2)} \quad (1)$$

Since steel moulds of 100mm by 100mm were used, therefore the Area (A)= 10,000mm^2

Table 10: Showing the compressive strength of concrete at 0%, 0.06%, 0.08%, 1%, 2%, 3% at 28 days.

% of sugar in concrete	0%	0.06%	0.08%	1%	2%	3%
Compressive strength at 7 days (N/mm^2)	13.0	17.5	17.0	0.6	0.0	0.0
Compressive strength at 28 days (N/mm^2)	19.3	26.0	26.0	1.0	0.0	0.0

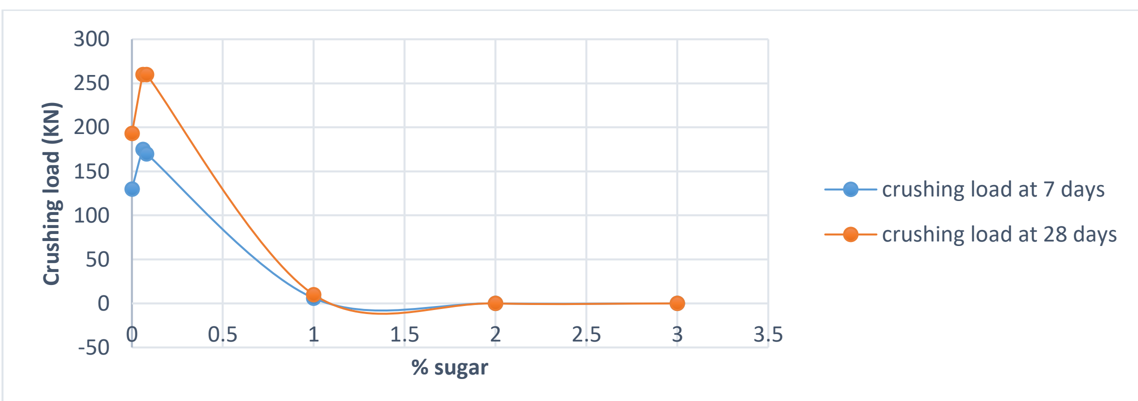

Figure 5: Graph comparing the results for the crushing load of the control concrete sample and other samples.

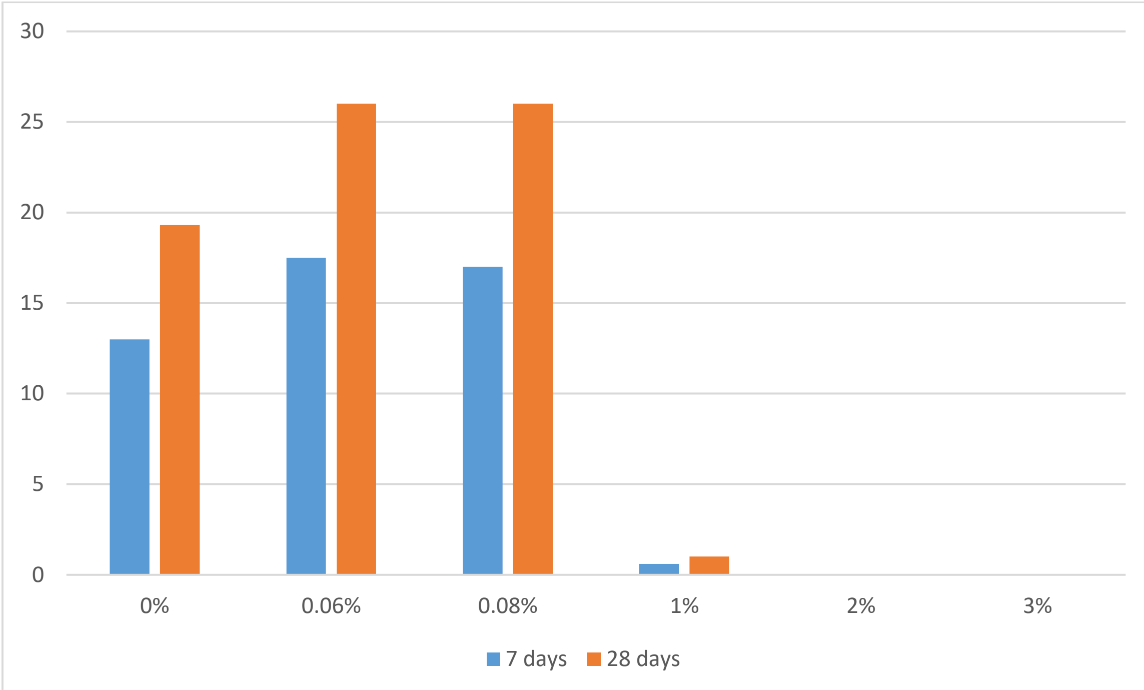

Figure 6: Graphical comparison of the compressive strength results obtained from the 0%, 0.06%, 0.08%, 1%, 2%, 3% concrete samples.

IV. Conclusion

The following conclusions are drawn from the present study:

i. The initial and final setting times for the control cement paste sample were obtained as 70 minutes and 328 minutes.

ii. The compressive strength of the control concrete sample at 28 days was obtained as 19.3N/mm^2.

iii. The initial and final setting times for 0.06%, 0.08%, 1%, 2% and 3% of sugar by weight of cement for the cement paste samples were obtained as 87 minutes and 467 minutes, 90 minutes and 480 minutes, 120 minutes and 495 minutes, 133 minutes and 510 minutes, 157 minutes and 540 minutes respectively.

iv. The compressive strength at 28 days for 0.06%, 0.08%, 1%, 2%, 3% of sugar in concrete was obtained as 26N/mm^2, 26N/mm^2, 1N/mm^2, 0N/mm^2, 0N/mm^2 respectively.

As outlined from the findings in this study, it becomes evident that the inclusion of sugar at replacement percentages of 0.06% and 0.08% proves to be highly viable. This conclusion is supported by the vivid enhancement in compressive strength shown by these percentages in comparison to the control sample. Additionally, these admixtures demonstrate a commendable ability to retard the initial setting time of cement paste, a noteworthy achievement that aligns seamlessly with the parameters outlined in [16] and [17]. This extension of setting time practically affords ample time for the seamless transportation of batched concrete from production facilities to the intended application sites.

REFERENCES

[1] W. Zhang and Y. Zhang, "Apparatus for monitoring the resistivity of the hydration of cement cured at high temperature," *Instrum. Sci. Technol.*, vol. 45, no. 2, 2017, doi: 10.1080/10739149.2016.1210635.

[2] F. Sayahi, M. Emborg, H. Hedlund, A. Cwirzen, and M. Stelmarczyk, "The severity of plastic shrinkage cracking in concrete: A new model," *Mag. Concr. Res.*, vol. 73, no. 6, 2021, doi: 10.1680/jmacr.19.00279.

[3] A. M. N. J.J.Brooks, "Concrete technology," *International Journal of Cement Composites and Lightweight Concrete*, vol. 9, no. 3. p. 186, 1987, doi: 10.1016/0262-5075(87)90058-3.

[4] Jacob Scot Roswurm, "Influence of Retarders on Shrinkage and Compressive Strength in Rapid Set Concrete," *University of Oklahoma*. 2018.

[5] G. Tzouvalas, G. Rantis, and S. Tsimas, "Alternative calcium-sulfate-bearing materials as cement retarders: Part II. FGD gypsum," *Cem. Concr. Res.*, vol. 34, no. 11, pp. 2119–2125, 2004, doi: 10.1016/j.cemconres.2004.03.021.

[6] J. J. Chang, W. Yeih, and C. C. Hung, "Effects of gypsum and phosphoric acid on the properties of sodium silicate-based alkali-activated slag pastes," *Cem. Concr. Compos.*, vol. 27, no. 1, pp. 85–91, 2005, doi: 10.1016/j.cemconcomp.2003.12.001.

[7] N. Bhanumathidas and N. Kalidas, "Dual role of gypsum: Set retarder and strength accelerator," *Indian Concr. J.*, vol. 78, no. 3, pp. 170–173, 2004.

[8] P. X. Duan, Y. Zhang, Y. C. Miao, and Y. Li, "A study of the influence of FGD gypsum used as cement retarder on the properties of concrete," *Adv. Mater. Res.*, vol. 374–377, pp. 1311–1319, 2012, doi: 10.4028/www.scientific.net/AMR.374-377.1311.

[9] S. M. Abd, Q. Y. Hamood, and Khamees, "Effect of Using Corn Starch As Concrete Admixture," *Int. J. Engg. Res. Sci. Tech*, vol. 5, no. 3, 2016, [Online]. Available: http://www.ijerst.com/currentissue.php.

[10] H. Zhang, W. Wang, Q. Li, Q. Tian, L. Li, and J. Liu, "A starch-based admixture for reduction of hydration heat in cement composites," *Constr. Build. Mater.*, vol. 173, pp. 317–322, 2018, doi: 10.1016/j.conbuildmat.2018.03.199.

[11] N. Aguilar-Rivera, "Bioindicators for the Sustainability of Sugar Agro-Industry," *Sugar Tech*, vol. 24, no. 3, 2022, doi: 10.1007/s12355-021-01105-z.

[12] G. Habert and C. Ouellet-Plamondon, "Recent update on the environmental impact of

geopolymers," *RILEM Tech. Lett.*, vol. 1, 2016, doi: 10.21809/rilemtechlett.2016.6.

[13] ASTM International, "ASTM C33/ C33M-16 Standard Specification for Concrete Aggregates," *ASTM Int.*, vol. i, no. C, 2016.

[14] B. S. I. BS 812: Part 109, *"Methods for Determination of Aggregates Moisture", British Standard Institution London, 1990.* 1990.

[15] British Standards Institution BSI, "BS 812: Part 2:1995 Testing aggregates, Methods of determination of density," *Br. Stand.*, no. 105, 1999.

[16] C. Arya, "Eurocode 2: Design of concrete structures," in *Design of Structural Elements*, 2015.

[17] ACI Committee 318, *ACI 318-14*. 2014.