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Effects of Sugar as Admixture on Setting Times and Compressive Strength of Concrete

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Abstract

This study aims to examine the influence of sugar as a retarding admixture on setting times and compressive strength of concretes produced with 2-different brands of Dangote and Sokoto cements produced in Nigeria. The samples of cement paste and concrete cubes were prepared with the percentage addition levels of sugar of 0%, 0.06% and 0.1% by mass of cement. The setting times test was conducted under room temperature and simulated 43^{o}C temperature using vicat apparatus. A mix ratio of 1:2:4 with water-cement ratio of 0.5 was adopted in the experiment and the compressive strength of hardened concrete specimens was investigated at 3, 7, and 28 days. The outcomes of the setting time test at a 43^{o}C temperature revealed that the control paste (0% addition of sugar) exhibited significant decrease in both initial and final setting times when compared with the results at a room temperature. However, with addition of sugar in both cement brands significant improvements in the setting times were recorded especially at 0.06% addition level. Furthermore, the results of compression test at 28 days revealed that control had 30.1 N/mm^2 while Dangote and Sokoto cements had maximum compressive strength at 0.06% addition of sugar of 33.4 N/mm^2 and 32.1 N/mm^2, respectively which represents 9.9% and 6.2% increase over the control specimen. The study therefore concluded that when an optimum percentage of 0.06% of sugar is added in the cement brands, it has the potential to increase the setting time and strength of concrete especially when concreting in a hot weather environment.

Keywords: Admixture, Cement, Compressive strength, Setting time, Sugar.

INTRODUCTION

Concrete is the predominant building material globally and holds a distinct position in the construction sector (Khan, 2006). In concrete technology, workability, setting time, strength growth rate, ultimate strength, and durability are the main attributes of both fresh and hardened concrete. These properties can be adequately achieved with proper mixing and supervision during the concrete production. However, Khan (2006) opines that there are situations when the properties described above can be negatively affected during the production of concrete as a result of hot conditions.

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Accordingly, Okereke (2003) observed that the Northen parts Nigeria, including Yobe, Yola, Kebbi, Sokoto and Maiduguri are classified as hot and arid areas in Nigeria, with temperatures ranging from 35 to 43^{o}C and a relatively low humidity of 40%. Furthermore, Ali *et al.* (2000) have observed that high ambient temperatures and low humidity are common indicators of the harsh weather. Therefore, managing the water cement ratio in fresh concrete mixes, which is the crucial element in concrete production, becomes more challenging when concreting these regions. Hot weather typically leads to unfavourable effects on concrete, including decreased workability, faster setting, higher water requirements, and reduced strength. These unfavourable characteristics contribute to difficulties in the process of concreting and might result in reduced durability (Ali *et al.*, 2000). According to Rana (2014), some admixtures can be beneficial in hot weather concreting by delaying the setting of the fresh concrete mixture and modifying the workability of the mixes. Myrdal (2007) states that a retarder admixture is employed to decelerate the rate at which the interaction between cement and water occurs. This is achieved by influencing the development of hydration process and diminishing the rate at which water infiltrates the cement particles; thus, the rapid setting of the concrete is minimized.

Retarding admixtures are chemical additive that slow down the first reaction between cement particles and water. It also extends the setting period and helps maintain the workability of the concrete (Alsadey, 2013). Additionally, Abalaka (2011b) discovered that retarder admixtures inhibit the quick solidification process exhibited by tricalcium aluminate, which leads to the formation of a false set in the fresh concrete. However, these admixtures are both imported and costly in Nigeria. Interestingly, Rathi and Kolase (2013) discovered that, sugar is a proven retarding admixture that is both cost-effective and easily accessible than other retarding admixtures. However, Neville and Brooks (2010) opines that the capacity of sugar to delay cement setting time is determined on the cement's chemical characteristics. Because, cement with lower levels of tricalcium aluminate (C_3A) and alkali content can be more effectively delayed than the cement with higher concentrations of these components (Myrdal, 2007). One possible reason is that when the C_3A level is lower, a lesser quantity of retarder is absorbed, allowing a larger quantity of the admixture to have an impact on and slow down the hydration process of the C_3S component. Therefore, the effect of sugar on setting times of cement depends on the chemical composition of a cement especially tricalcium aluminate (C_3A) contents. Based on this phenomenon. This study examines the impact of sugar as admixture on the setting times and compressive strength of concretes produced using 2-brands of Portland cement readily available in the North part of Nigeria.

MATERIALS AND METHOD

Materials

Portland cement

In this study, the ordinary Portland cements employed in the experimental work include Dangote and Sokoto cement brands. They were procured from accredited dealer in Zaria City, Kaduna State. The chemical and physical properties of the cements were in conformity with prescribed requirements of ASTM C150 (2005).

Retarding admixture

The retarding admixture employed in this experimental work was sucrose, commonly known as table sugar. The sucrose utilized was a white crystalline solid, specifically Dangote sugar brand, which is soluble in water.

Aggregates

The coarse aggregate utilized in the experimental work was crushed granite stones. The aggregate was sifted using standardized sieves, and the portions that passed through the 10 and 20mm maximum sieves were used. The fine aggregate (FA) utilized was naturally occurring, uncontaminated river sand with angular shapes. To eliminate contaminants, the material was filtered via a typical BS 4.75mm sieve, and only particles that passed through the sieve were employed in this investigation.

Method

Setting times test

In this study, two different brands of cement were used which include; Dangote and Sokoto cement brands. Three distinct samples of cement pastes were prepared by adding sugar to the percentage levels of 0. 06 and 0.10% by mass of cement in the setting times test. The test was conducted at two distinct temperatures: 27°C, which is the typical laboratory room temperature, and 43°C, which is the approximate maximum ambient temperature for Maiduguri, Yobe, Adamawa, Sokoto, etc which are considered as hot regions in Nigeria. The test was carried out in compliance with the BS EN 196–3 (1987) standard.

Preparation of the concrete specimens

The ingredients were weighed and batched according to their weight. Mixing was performed using a concrete mixing machine, following a ratio of 1:2:4, with a water-to-cement ratio of 0.5. The sugar content in the cement was 0.06% and 0.10% by weight, while the control (0%) had no sugar content. Prior to adding it to the concrete mixture, the sugar was completely dissolved in water, resulting in a certain amount of sugar in the solution. The mixing was conducted in compliance with the specifications outlined in B.S 1881- 125 (1986). During the casting of the concrete specimens, fresh concrete was poured in the metal mould of size 100mm x 100mm x 100mm in 3-layers, each layer was manually compacted with 25 strikes before the next layer was poured.

Workability test

In order to determine the workability, the slump values of the fresh concrete mixes of 0%, 0.06% and 0.10% percentages of addition of sugar by mass of cement was measured. The slump test was conducted as per the specifications stipulated by B.S EN 12350-2 (2009). In this test, a metal mould cone was used and the mould's internal surface was cleansed and lubricated with engine oil. Subsequently, it was secured securely against the surface by placing it on the sampling tray. The mould was removed vertically upward after the fresh concrete was poured into it in 3-layers, each layer being tamped 25 strokes and occupying approximately one third of the mould's height. The slump value was obtained as the vertical distance between the height of the mould and the level of the concrete after it settled.

Compression test

The compression test was performed at 3, 7 and 28 days periods for all the specimens and it was done on the cube sized 150mm × 150mm × 150 mm using HEICO compression testing machine of 3000kN capacity and the rate of loading applied was 5.15 kN/sec. The test was performed in agreement with the specifications given in BS EN 12390-1 (2000). The values of compressive strength were obtained directly from the compression machine after the failure of the specimen.

RESULTS AND DISCUSSION

Setting time

Figure 1 illustrates the test findings for the setting times of cement pastes prepared with different percentages addition of sugar of 0%, 0.06%, and 0.10% at room temperature (27°C). The cement pastes were made using two different brands of cement, namely Dangote and Sokoto cements. The findings indicated that the initial and ultimate setting times consistently rose as the proportion of sugar added to the weight of cement increased. For control paste, the initial setting times for Dangote, and Sokoto cements 111 and 125 minutes respectively. However, at 0.06% addition of sugar, the initial setting times increased significantly to 270 and 370 minutes for Dangote, and Sokoto cements respectively, which represent 143% and 190% increments in the initial setting compared to the control pastes (0%). Similarly, at 0.10%, the initial setting times observed for Dangote and Sokoto cement brands were 320 and 440 minutes respectively as against control pastes with 111 and 125 minutes. Similar trends were observed in the final setting times of the cement brands. The prolonged setting times seen in all cement brands when 0.06% and 0.10% percentages of sugar were added in the cement brands could be attributed to delayed hydration caused by the presence of sugar molecules. Because, the molecules raise the levels of calcium, aluminium, and iron in concrete. The sugar molecules undergo a chemical reaction with these metals, resulting in the formation of insoluble chemical complexes that stick to the cement particles. The duration of the setting process is prolonged as a result of the adsorption of sugar molecules, which create a thin layer on the cement particles.

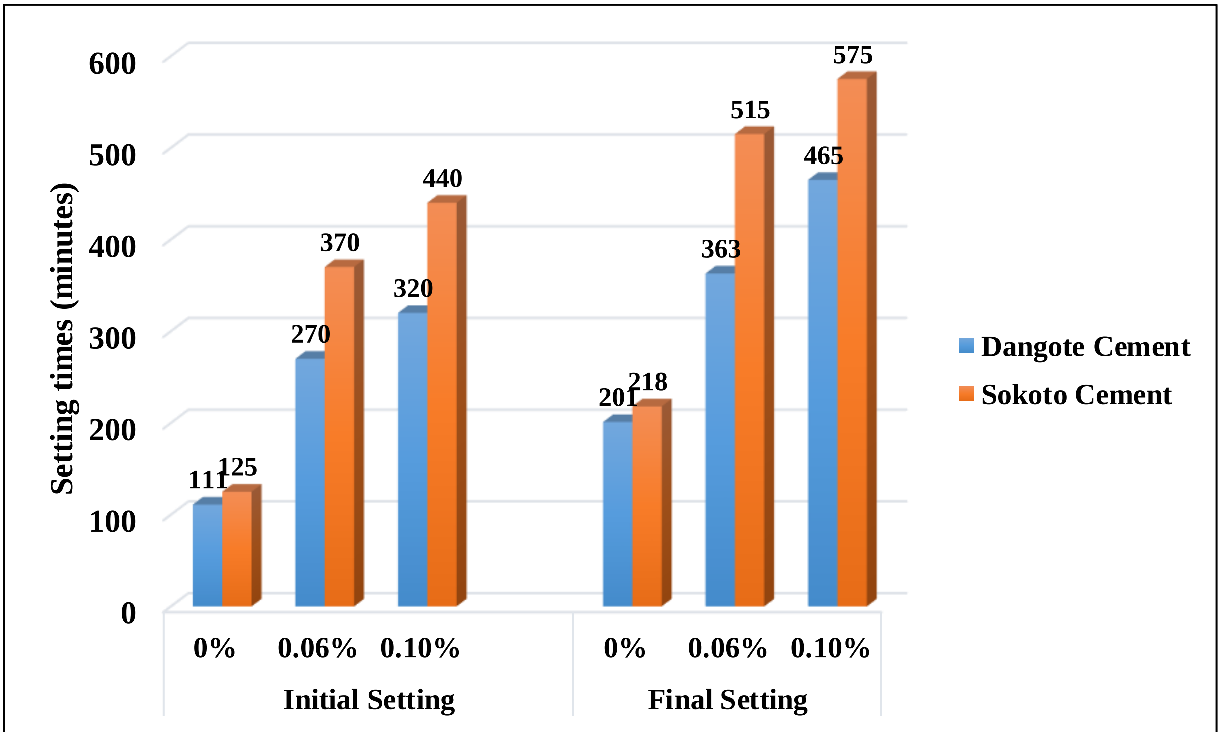

Figure 1 Setting times of Dangote and Sokoto cement at room temperature (27°C)

The results of setting times test performed at the simulated temperature 43°C are presented in **Fig. 2**. Typically, when the temperature is raised to 43°C, the control pastes of Dangote, and Sokoto cements had a reduction in their initial setting periods by 122%, and 108.3% correspondingly, compared to the control pastes at 27°C as it can be seen in the Fig.1. The observed phenomena can be ascribed to the correlation between increased temperature and the internal temperature due to hydration process, resulting in an accelerated chemical reaction rate. Consequently, this accelerates the solidification process of the cement paste as discovered by (Nensok, 2010). To mitigate the rapid decrease in setting times, all tested cement brands were supplemented with 0.06 and 0.10% of sugar at a temperature of 43^{o}C. At a concentration of 0.10%, two cement brands exhibited a greater percentage increase in initial setting durations compared to the addition of sugar at a concentration of 0.06%. The percentage increases seen were 175 and 124 percent for Dangote and Sokoto cement brands, correspondingly compared to control paste. Furthermore, it is evident that there was a rise in the final setting times for all cements as the percentage of added sugar increased. Specifically, Sokoto cement experienced a higher increase of 108% in relation to the control paste. This occurrence may be attributed to the relatively low concentration of tricalcium aluminate (C_3A) in comparison to Dangote cement brand. This observation aligns with a previous discovery made by Myrdal (2007).

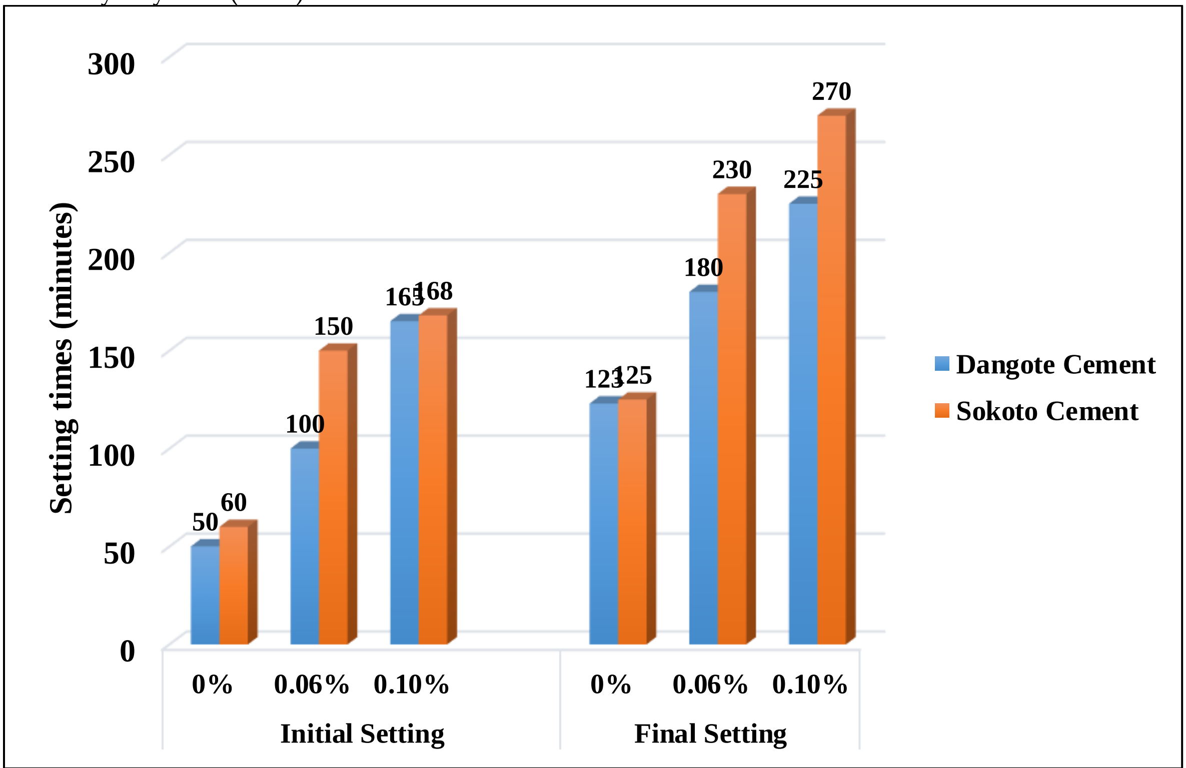

Fig. 2 Setting times of Dangote and Sokoto cement at simulated temperature of 43^{o}C

Workability

Fig. 3 depicts the results of slump values for the 2-brands of the cement. It can be observed that the slump values increased as the percentage level of sugar incorporation rises for all the brands of the cement. The slump values recorded for the control samples of Dangote, and Sokoto cements were observed to be 7.0mm and 10mm respectively, this shows that the degree of workability was very low (Gupta and Gupta, 2010). But at 0.06% inclusion of sugar all the cement brands recorded the higher increases in slump of 20mm and 18mm for Dangote and Sokoto cements which represent 185% and 80% increase over the control. At 0.10%, a significant increase was observed in the slump. The values recorded for Dangote and Sokoto cements were 48mm and 30mm respectively. This represents a medium degree of workability. The increased slump values seen in the fresh concrete containing 0.06% and 0.10% added sugar can be attributed to the presence of sugar molecules. Because, sugar produces a thin layer on the cement particles, which slows down the hydration process and ultimately leads to improved workability. This result aligns with the earlier research findings documented by Giridhar *et al.* (2013).

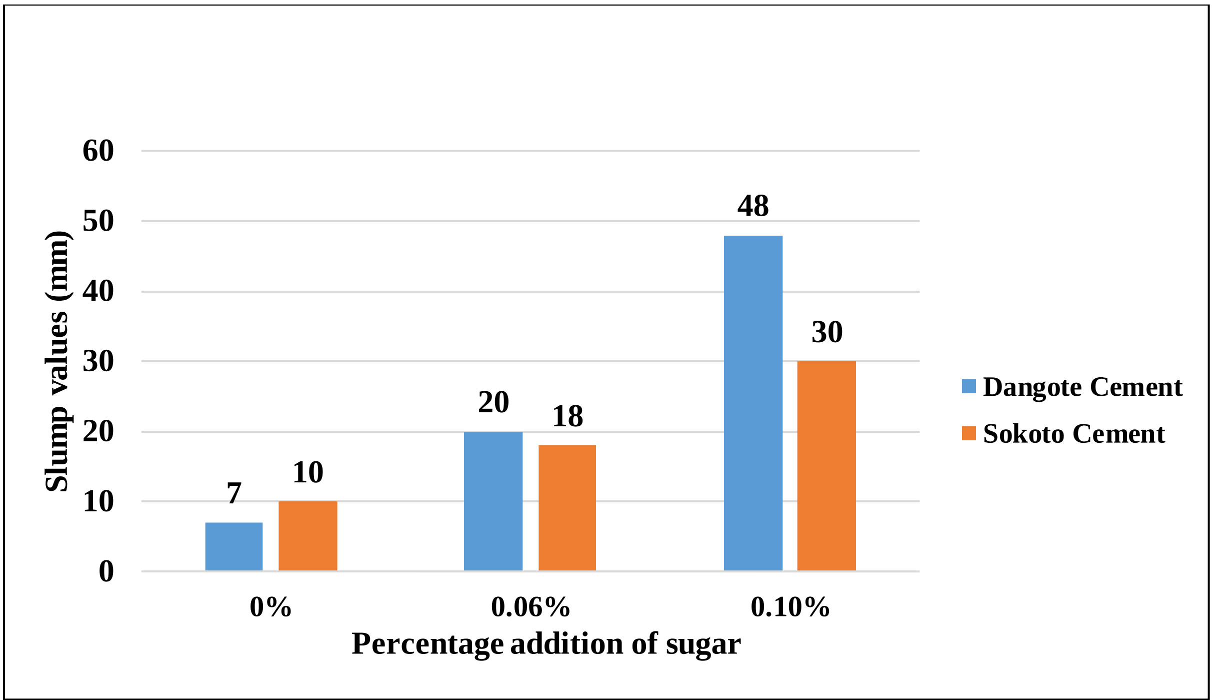

Fig. 3 Slump values of fresh concrete mixes made with Dangote and Sokoto cements

Compressive strength

Fig. 4 illustrates the compressive strengths of Dangote and Sokoto cement brands at a curing period of 3, 7, and 28 days. The compressive strength of control specimens of Dangote and Sokoto cement brands was measured at 15.8 N/mm² and 14.3 N/mm² respectively after 3 days. However, after 0.06% was added, the strength decreased to 12.0 N/mm² for Dangote cement and 11.0 N/mm² for Sokoto cement. These values represent 31.6% and 30% decrease in compressive strength when compared with the control. Furthermore, at 0.10% similar results were observed. The compressive strength values recorded for Dangote, and Sokoto cement brands were 10.0 N/mm² and 9.1 N/mm² respectively. The decline in the initial compressive strength of Dangote and Sokoto cement brands can be attributed to the retardation effect of sugar in the cement, which greatly reduces the early strength of the concrete. This discovery corroborates Neville's assertion made in 2006. One possible explanation is that the presence of sugar molecules might induce a delay in the reaction between C_3S and C_3A, which leads to a slower development of early strength.

However, at 28 days curing period, an appreciable rise in compressive strength was achieved at 0.06% in relation to the control. The compressive strength achieved at 28 days for Dangote and Sokoto cements were 33.4 N/mm², and 32.1 N/mm² with their corresponding controls having 30.5 N/mm² and 30.0 N/mm². This shows 9.5% and 7.0% increase in compressive strength over that control concrete. Though, as the percentage addition of sugar increased to 0.10%, the compressive strength declined again when compared with control. The compressive strength recorded for the Dangote and Sokoto cements were 29.2 N/mm², and 28.0 N/mm². Hence, the optimum proportion for sugar to be use in the Dangote and Sokoto cement brands is 0.06%. The observed enhancement in compressive strengths with the addition of 0.06% sugar can be attributed to the utilisation of sugar as a concrete set retarder. After around seven days, the concrete progressively regains its strength and surpasses that of non-retarded concrete, despite the fact that its starting strength is reduced. This is because a more compact cement gel is produced and the cement paste takes longer to solidify. This result is in line with a previous study conducted by (Rathi and Kolase, 2013).

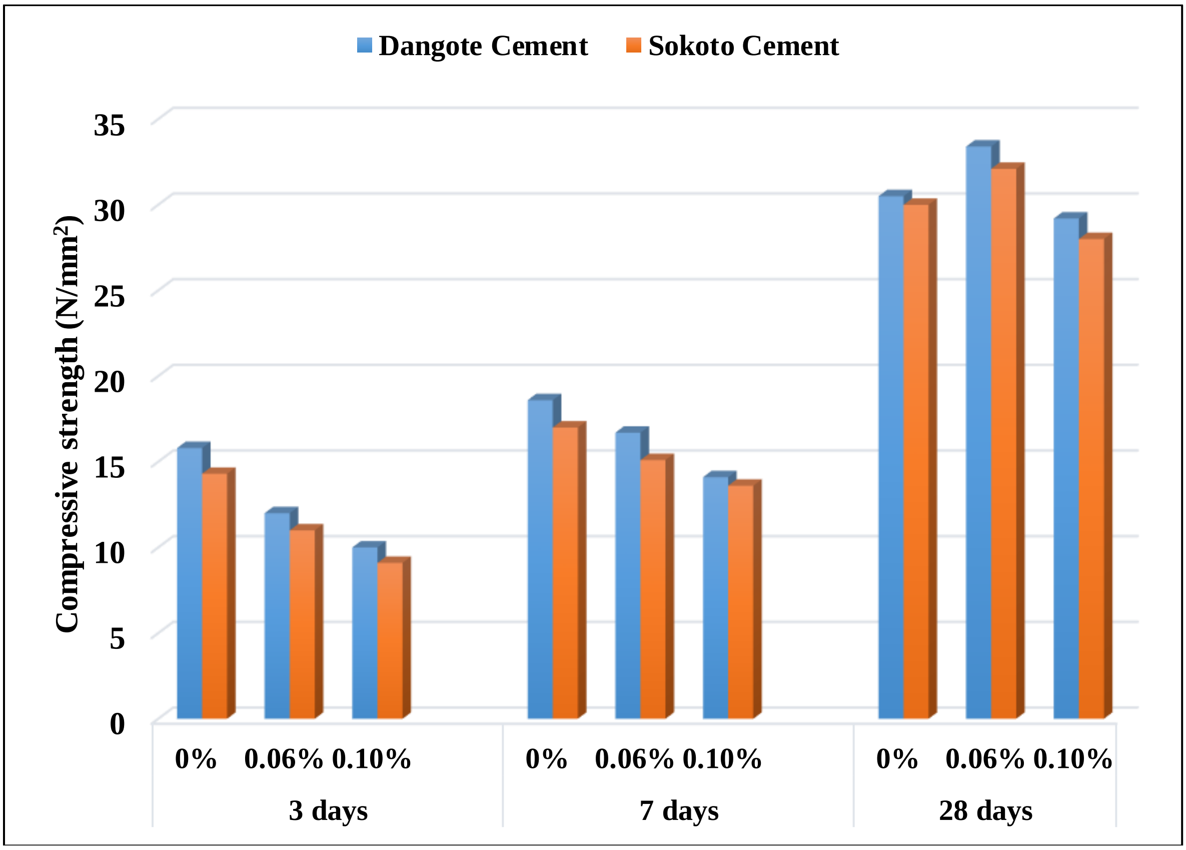

Fig. 4 Compressive strengths of the Dangote and Sokoto cement with 0%, 0.6% and 0.10% addition of sugar

CONCLUSION

From the results of the study on the effects of sugar as admixture on concrete produced using Dangote and Sokoto cement brands, it can be inferred that:

i. The initial setting times of the control cement pastes made with Dangote and Sokoto cements reduced significantly when subjected to the simulated temperature of 43°C by 123% and 108.3% respectively when compared with the initial setting times at of 27°C (room temperature).

ii. The inclusion 0.06% of sugar in cement brands resulted to a reasonable rise in the initial setting times of the cement brands at the simulated temperature of 43°C.

iii. The workability (slump) of the fresh concrete mixes made with Dangote and Sokoto cements improved significantly with the inclusion of 0.06% and 0.10% of sugar by mass of cement.

iv. The early strength (i.e., 3 and 7 days) of concrete made Dangote and Sokoto cement brands with inclusion of 0.06% and 0.10% of sugar declined in comparison to the control concrete.

v. At 28 days, the compressive strength of Dangote and Sokoto cement brands increased by 9.5% and 7.0% over control with a 0.06% inclusion of sugar. However, at 0.10%, the compressive strength of cements reduced significantly in relation to the control. Therefore, 0.06% is the optimum percentage of addition of sugar in Dangote and Sokoto cement brands.

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